Reader Comments

Transforming Learning with Technology Redux

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We agree with much of what Bush and Mott say (2009) in their stimulating and thought-provoking analysis about transforming learning with technology. As proponents of Advanced Distributed Learning (ADL) (Fletcher, Tobias, & Wisher, 2007), we have advocated making platform independent instructional objects readily available over the Global Information Infrastructure. We have also endorsed making learning accessible anytime and anywhere (Fletcher & Tobias, 2008). Therefore, we endorse Bush and Mott's advocacy for interoperable, modular, open tools (courseware and related software) to facilitate learning. We respond to their interesting article from the joint perspectives of its implications for present research and practice in the domains of learning from instruction, and its improvement in the future.*

We view the present and future perspectives as complementary. Bush and Mott's thoughtful article extends present knowledge, as they intended, in order to stimulate movement to new practice and research approaches. Our perspective helps to identify some of these. From the futurist perspective, we extend Bush and Mott's thinking by anticipating an even more distant future than they describe. The future we point to is not hard to envision from our present capabilities, both in laboratories and in the marketplace, but it appears as desirable to us as it did to Suppes (and Plato) (1966). Our view of this future may stimulate thinking and needed research to approach it.

Present Learning from Technology

We were especially pleased to read that "supporting effective, dynamic, learning is the primary aim—the nature of the tools used and their source are both of secondary importance" (Bush & Mott, 2009, p. 3). The authors also indicate that innovations using educational technology have often promised more than they could deliver. Innovators may have been so bedazzled by the technological affordances of new technology that the difficulties of integrating new approaches into existing educational practice were vastly underestimated. As indicated elsewhere (Tobias, 2009), educational technology enthusiasts led our late colleague Richard E. Snow to remark that the literature on instructional innovations was often little more than a random walk through the garden of panaceas.

Clearly, technology has greatly reduced the difficulties of accessing and displaying rich instructional materials. But it has not always ensured that there is a knowledge base enabling students to learn more from technology-based instruction than from existing delivery systems. Computer games, which are widely reputed to be excellent instructional vehicles (Gee, 2003; Shaffer, 2006; Squire, 2006), are a case in point. Clark (2007) and Hays (2005), among others, have indicated that, despite strong advocacy, the superiority of games compared to other instructional methods has *not* been established. Munro (2008) found that participants at a *Serious Games Summit* "admitted that initial expectations for automatic learning from games have not been realized" (p. 57). Our own continuing review of the games research literature (Fletcher & Tobias, 2006; Tobias & Fletcher, 2007) suggests that although computer games are promising, their demonstrated instructional effectiveness is currently limited to a relatively narrow set of circumstances. Principles for designing games that reliably produce given instructional objectives have yet to be developed. Nevertheless, these considerations have not dimmed anyone's enthusiasm for computer games in either the educational or training communities.

Similarly, constructivism appears to be the predominant contemporary influence on classroom instruction, and the preparation of instructional materials—technology-based or otherwise. Nevertheless, the effectiveness of constructivist instruction has been seriously challenged (Kirschner, Sweller, & Clark, 2006; for extended discussions of this issue by both supporters and critics of constructivist approaches, see Tobias & Duffy, 2009). The current interest in both games and constructivist instruction demonstrates that enthusiasm for an approach or innovation does not assure the presence of adequate research support for its usefulness.

Bush and Mott (2009, p. 6) indicate that "The vast majority of educational technology implementations to date have been focused on making things more effective and efficient for institutions and teachers, and not necessarily on improving outcomes for learners." That development may not be entirely negative. Once the capabilities of educational technology (described more fully from the futurist perspective below) become routine, it is important that researchers insist that issues dealing with improvement in learning receive attention. One of the most positive aspects of online, or other modular instructional approaches, especially ADL and its Shareable Content Objects Reference Model (SCORM), is that the courseware can be changed more easily than teachers' behavior in classroom instruction. If some modular materials are found to be ineffective, improving them is less difficult than improving teachers' practices.

Bush and Mott advocate placing desirable and achievable goals just out of reach, to create the ideal conditions for learning that would arouse curiosity and engage intrinsic

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motivation. That idea is similar to Vygotsky's zone of proximal development (Chaikin, 2003), Yerkes and Dodson's (1908) Inverted "U," and the construct of instructional support (Tobias, 1982). As suggested elsewhere (Tobias, 2009, p. 344) "it is more of an art than it should be to offer only the support students need to learn, and withdraw or withhold support when they can determine for themselves what they need in order to succeed." Teaching skills and the ability to develop instructional materials are likely to be normally distributed, as are virtually all human characteristics. Therefore the majority of instructors and developers will be average practitioners rather than artists and need research-based prescriptions to determine the ideal amount of instructional support, as well as other instructional practices.

We welcome Bush and Mott's emphasis on student learning, rather than instruction delivered by technology. One reason that we wander in Snow's panacea garden is that too little about human learning in meaningful contexts is known to make instructional prescriptions, including prescriptions for optimal instruction support. In medicine it took many years of research before patients' temperatures could be assessed reliably with thermometers rather than obtaining subjective impressions of it by touching them. We suspect that the science of learning from instruction is still more "touchy feely" than based on a robust knowledge base similar to that which led to the development of the thermometer.

Of course, we share Bush and Mott's enthusiasm for ADL and SCORM. Developing a standard permitting ready access to modular, platform-independent instructional objects over the Internet is a major technological accomplishment. However, as noted elsewhere (Tobias, 2008a, b) it is important that this technological feat is accompanied by attending to critical questions dealing with learning from instruction. There are numerous such questions, and we will list only some major ones such as: (1) How can the effectiveness of ADL self-contained instructional objects (SCOs) be determined by potential users? (2) What prior knowledge is assumed by SCOs? (3) How can we best match SCOs to the needs of individual users? A key objective of the ADL vision is the adaptation of SCOs to student characteristics. Such instructional adaptations, and those described below, depend on finding reliable interactions between student characteristics and instructional treatments, an area that has been investigated for some time (Cronbach & Snow, 1977; Gustaffson & Undheim, 1996; Shute, Lajoie, & Gluck, 2000; Tobias, 1989, 2003, 2005), but the need for research-based instructional prescriptions remains.

The questions about instruction listed above are controversial for all instructional approaches; hence it may seem unfair to expect future versions of SCORM, or other technological innovations, to resolve them. But, as Bush and Mott point out, it is important to recognize these concerns, conduct research addressing them, and modify instruction as new findings emerge.

We hope that our reactions, the stimulating article by Bush and Mott (2009), and other discussions (Barr, 2009; Everson, 2009; Roberts, 2008) will lead advocates of educational technology to pay more attention to questions about learning, beyond the few listed above, and many others we did not have the space to describe. Of course, it is an admirable technological feat to permit ready access to platform-independent, modular instructional material. That is one of the hallmarks of ADL, SCORM, and the changes in orientation that Bush and Mott recommend. But, as they recognize, focusing only on them runs the danger that the technology will continue to push issues of effective learning permanently into the background where they may never be answered.

Back to the Aristotelian Future

By reminding us of Patrick Suppes' prophetic vision of an Aristotle for every Alexander (Suppes, 1966), Bush and Mott take us to the very brink of where we may be going. But there they stop—leaving uncertain the connection between accessible, reusable, digital learning objects and the new instructional future that our "best thinking and efforts" (p. 3) may take us to. Making that connection might help us all see where we may be headed—and help focus our research efforts.

Of course, the future we envision relies heavily on computers and technology more generally. Physically, where would the computers be located? They might be hand-held, more probably worn as an accessory, or even implanted with functionalities that include wireless connectivity, natural-language interactivity, and understanding. The technology could access the full universe of relevant knowledge updated in real time and made available on demand. We may not have to wait until the middle of the 22nd Century before we boldly go into this future. Much of it may already be here and but too disorganized to be readily recognized.

Google, perhaps the pre-eminent present instructional and problem-solving technology, is only a beginning. We can ask Google questions and it responds with precise answers, if we are lucky, or thousands of candidate answers if we are not—but that may be a solvable problem (Dodds & Fletcher, 2004). Computer programs with sufficient, albeit limited, natural-language understanding to support instructional and problem-solving dialogues have been available since the 1970s (Brown, Burton, & DeKleer, 1982) and earlier (Weizenbaum, 1966). Similarly, successful adaptations of computer interactions to individual learners have been available since the 1960s (e.g., Atkinson & Wilson, 1969; Fletcher, 1975; Suppes, Fletcher, & Zanotti, 1976; Suppes & Morningstar, 1972) even to the extent that Vinsonhaler and Bass were able to publish a meta-analysis in 1972 that reported on the experiences of thousands of students with various individualizing computer-assisted instruction programs.

What has developed since the 1970s, in addition to vastly more powerful computing technology, is the global information infrastructure, currently in the form of the Internet and the World Wide Web, supplying massive amounts of information (and misinformation) that is becoming available everywhere.

Let us now return to sometime around 380 BC. How was learning conducted in Plato's Academy? According to the historical record, students engaged each other and the master in conversation, as occurred for much of human existence. An interested learner could question a sage or master who, with luck, understood what the student needed, and the level of detail and abstraction required in order to learn. The master would then engage the learner in a question and answer dialogue intended to achieve the student's objective(s).

By providing an Aristotle for every Alexander (Suppes, 1966), or a Mark Hopkins for everyone else (Dodds & Fletcher, 2004), we are simply getting back to our roots. However, today's technology has made individualized, mixed-initiative, tutorial interactions available to many more of us, not just to Greek and Macedonian aristocrats. These interactions are becoming both affordable and ubiquitous. By finding our way back to this future, we may be on the brink of another major revolution in learning that started about 7,000 years ago with writing, which made the knowledge of masters available without their physical presence—for those with the physical strength to carry around clay tablets or the resources to afford papyrus rolls.

A second revolution grew from the development of movable type—by the Chinese in about 1000 AD and by Gutenberg in around 1439 (Kilgour, 1998). That eventually made human knowledge affordable and available to the middle-class masses it helped to create. Bush and Mott remind us of this with their discussion of Bühler (1952) and how the ubiquitous availability of text paved the way to modern scholarship. Finally, we have computer technology that is not only making human knowledge ubiquitous, available, affordable, and cost effective (Fletcher, 2006) but can also restore the mixed-initiative conversational interactions for transmitting knowledge. In Bush and Mott's terms, learning can be made learner-centric with malleable content and tools by tapping into a comprehensive network of human information and knowledge.

Bloom (1984) laid down a 2-Sigma challenge with his students' finding that the difference between classroom learning and individual tutoring amounted to 2 standard deviations. Individualization then appeared, as Scriven (1975) had pointed out, an educational imperative, and an economic impossibility. A major benefit of computer-assisted instruction, as Fletcher (1992, 1997) and later Corbett (2001) argued, is that, in addition to whatever other benefits it provides, the technology makes Scriven's educational imperative affordable. What, then, do the networks and the SCOs, discussed by Bush and Mott, have to do with this real and quite valuable possibility? What's the connection?

The digital objects discussed by Bush and Mott, Dodds and Fletcher (2004), and Fletcher, Tobias, and Wisher (2007) may supply the building blocks for individualized, tutorial, computer-assisted, mixed-initiative, guided interactions (made sharable, portable, and reusable by SCORM) that enable learners to achieve their goals. These objects may be similar to the type elements that supply the sharable, portable, and reusable building blocks of printed documents. Bush and Mott lead us to SCORM, LETSI, and future versions of SCORM. The next step is to link the world of SCOs and networks with guided individualized dialogues, or conversations. Perhaps we are not yet at Gladwell's (2002) tipping point, but, on the basis of what Bush and Mott tell us, we seem to be creeping up on it.

It may be time to eschew the current education culture described by Bush and Mott as one that promotes "caution and satisficing rather than experimentation and innovation" (p. 7). Instead we can focus on where we seem to be inexorably headed. Many challenging issues still need to be resolved by research in order to develop technology-based capabilities that pull these objects out of the global information infrastructure and assemble them in real time and on demand for the instructional, interactive, and individualized dialogues we envision. That is the challenge for instructional technologists, cognitive theorists, and their allies in information technology. Particularly important questions, in order to connect SCORM's digital objects to instructional question and answer dialogue, might include the following:

- What should the size or "granularity" of objects be? Clearly, the approach of treating entire courses or even course modules as instructional objects will not get us very far. Such objects are portable but often too large and ungainly to be reused and assembled for individualized interactions with learners. SCORM specifications are, in the words of its developers, unhelpfully agnostic (e.g., Dodds & Fletcher, 2004) in this regard.

- What specifically does a machine need to know about a learner's knowledge, skills, attributes, motivations, etc., to assemble and devise an individually appropriate instructional dialogue? How should we access this information as continuously and unobtrusively, as Fletcher (2002), VanLehn (2005), and others have suggested? Development of the Semantic Web with its ontological capabilities to identify links between both related and seemingly unrelated knowledge domains (Berners-Lee, Hendler, & Lassila, 2001) will help us build more sophisticated, elaborate, and comprehensive models of learners. That development, or something like it, seems necessary, but not sufficient to deal with the mass of cognitive activity.

- Once the machine has collected and assembled the necessary information on the learner's current state, what should it do to devise instructional and/or problem-solving dialogues to get from here to there, i.e., how can it lead a learner to the desired end state? Perhaps we need to return to a more recent, but still early future that dealt with parameterized transition states (Atkinson & Paulson, 1972; Fletcher, 1975). How should it guide learners/users to their goals reliably—so that all students get what they need (e.g., Clark, 2005)? This issue suggests the future development of these interactive dialogues, not as a matter of art or science, but of instructional engineering (e.g., Woolf & Regian, 2000).

These are all engaging and important challenges. Efforts to meet them will have a significant impact on the environments we create to help people learn. But there are other, more difficult, challenges here. Once we have gotten to Google and beyond, once there truly is an Aristotle or Mark Hopkins readily accessible to us all, what then is the role for classrooms, classroom instruction, and classroom instructors? More generally, schools and all our existing instructional institutions play essential roles in our lives. How will their roles change in the future we have outlined? Educators and educational researchers, in technology and elsewhere, should prepare for where this future seems to be leading. Without their active, concentrated involvement, the future will not be in our hands but in the hands of less knowledgeable others.

We may be able to ignore some issue—like natural-language processing, hardware and software engineering, and digital communication—because they are being addressed by others. However, instructional researchers need to make significant progress on adapting instruction and instructional conversations to students, as discussed above, before learners can be taught by a technological master tutor. It seems doubtful that machines by themselves will provide dialogues that are precisely those of a master, human tutor. Compared to human tutors, computers have greater strengths in some areas (memory retention, retrieval, processing speed) and greater weaknesses (empathy, aesthetic sensibility, abductive reasoning) in others. Major research efforts will be required to blend these strengths and weaknesses of computers to engage in effective instructional conversations.

Despite the ingenuity of our software and instructional designers, it seems unlikely that we will understand these strengths and limitations well enough for many years—the problem is not with knowing enough about machines, although that remains an issue. The more difficult problem may be to learn enough about ourselves and how we learn optimally so that we can create learning environments that reliably enable individuals to achieve the goals they seek.

In any case, the "Columbus effect" (Fletcher 2004) will come into play as it did with horseless carriages, wireless telegraph, and microwave transmission. It will lead us to places, applications, and capabilities that we have yet to imagine. As Bush and Mott suggest, we should boldly go wherever all this takes us. □

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